Making body temperature lower to raise the safety level of firefighters' intervention

Anett Urban, Ágoston Restás

Institute of Disaster Management, National University of Public Service, Budapest, Hungary. Corresponding author: A. Urban, urban.anett@uni-nke.hu

Abstract. Protection of the first responders has always been a highly important issue both in the past and nowadays. The different standardized protective equipment and several compulsory professional trainings try to improve the protection of our firefighters to a higher level. In spite of the continuous improvements, the thermoregulation system of the firefighters is strained by the high external temperature, furthermore it increases the use of the circulatory system, the water and sodium balance in the body that they need to work in full-body covering clothes. We need to know that the heat can cause not only significant wellbeing and performance decrease but also heat slump, heatrun-down, heat stroke, and the decrease of the ability of concentration can easily contribute to dangerous, even life-threatening situations. In some cases this can even be fatal for the firefighters. In addition to reviewing literature related to the above topics, the goal of the authors is to research and present the equipment and possibilities that can help lowering the body temperature of the firefighters in order to reach better performance during the interventions. Use of equipment lowering body temperature allows the decrease of heat strain caused by the environment and the personal protective clothing in case of fire, accidents involving transportation of dangerous goods or forest fires which can be a prolonged intervention.
Key Words: firefighter, body temperature, safety of intervention.

Introduction. The requisite of effective use of human resources challenges greatly the fire departments of several countries. It is very important that the personal strength of fire departments should consist of people in appropriate number, who are ready and able to do their jobs, so they should be well-trained, specially skilled, motivated, trained professionals. At the scene of the damage the intervention – which can be a 1-2-minute long fire up to a many-hours-long duty – sets the firefighters' organism to an inordinate physical pressure. Human organism - depending on age, physical and toughness level – adapts differently to the pressure on it. In the case of firefighters we have to pay attention to extreme heat effects, spasms and circular problems caused by liquid- and salt deficiency. As a result of these even death might occur (Kanyó 2008).

The effect of heat on human organism. Humans are one of the most tolerant creatures on Earth, so we can hustle for longer periods even between -30 and 45^{o}C. Despite of the extremes the sustainability of operability of our organisms is possible between certain temperature boundaries. The organism can only partly compensate the changes with its body temperature level keeping mechanism. Under circumstances warmer than our body temperature (36.3 -36.8^{o}C) the body has to increase heat egress, while during colder circumstances, it has to decrease it (Pavlik 2013). Further temperature increase or decrease without adequate defence might lead to death. In case of overheating the body tolerates by heat egress. This time the veins of the skin expanse, more warm blood gets on the surface of the body, sweating starts, which is a cooling mechanism. During this process our body distracts blood and liquid from other parts of the body, which worsens the performance.

If the environmental temperature rises above the neutral zone, beside the oxygen consume the heat production rises as well. This fact obviously is not ideal from the heat conditioning point of view, because the sustainment of constant body temperature really charges the organism. The reason for this phenomenon is said to be found in the so called van't Hoff (empirical) rule, which says that by the increase of the temperature by 10^{o}C, the speed of reaction grows up by 2-4 times (Lorenz et al 2007). In case of firefighters this is really important, as during an operation a bad decision might result in the death of their own or partners or the civilians.

Contingencies while firefighting. Basically there are two sorts of heat dangers threatening the firefighters: burnings and heat load. Outer heat effects and work load do not influence body temperature equally. Outer heat first has to get through clothes and skin, before influencing body temperature, while work load first the inner temperature of the body increases before leaving through the skin. If the environmental temperature is higher than the body temperature, the heat surplus can only be egressed by sweating (Nádori et al 1998). The evaporation should take care of the compensation of outer temperature. According to American statistics, only 3% of accidents during firefighting are burns. During firefighting, the number of deaths is very high. More than 51% of the victims die because of heart attack, and only 16% because of burning und asphyxiation or smoke inhalation. (Rita et al 2016a, b). According to estimates, 80-90% of accidents are caused by incorrect situation awareness and it is also known that the concentration ability dramatically decreases as body temperature increases. This is the van't Hoff-rule (Cohen 1912), so it is assumable that most of the accidents are caused directly or indirectly by the overheatment of the body.

Circumstances during firefighting. It is an essential rule that warmer body egress heat to colder ones, with which its own body temperature decreases, and the colder one's increases. Organisms produce heat during their functioning: app. 80 W while sleeping, and more than 1000 W during intensive work. The bodies of firefighters produce 300-500 W heat during work, and they can egress it by breathing, by dry heat conveyance and by evaporation (Kanyó 2014). At room temperature and 50% relative moisture (RH) the egress leaves 20% by evaporation, 25% by conveyance, 45% by heat radiation and 10% by breathing. If the environmental temperature reaches 35^{o}C, the only way of cooling the body is evaporation. Evaporation is a very effective method, because one litre evaporated sweat takes 672 W out of the body. The amount of evaporated sweat decreases as time goes by. If the body is affected by heat charge, sweat becomes stronger at the trunk. The higher the body temperature is, the lower skin temperature is needed to start sweating. During firefighting the protective clothes strongly insulate, so the body is not in a heat balance with the environment and a part of the produced heat piles up in the body. Beside observing the burn injuries, it has also been observed how much heat charge does firefighter equipment cause to the firefighters' organisms. The results strongly differ from each other depending on outer conditions of the measurements (temperature, moisture) and the quality and vapour permeability of the clothes. The quantity of the clothes also has to be taken into consideration (a 24 kg heavy equipment reduces the person's performance by 25%) as well as the fact that moving in such equipment how much more heat production it causes in the organism (Petrekanits 2002). By knowing the allowed maximum body temperature, in principle, it can be counted to each equipment that after how much work should the person stop to prevent any dangerous situations. We also have to take into consideration that body temperature keeps rising for minutes even after stopping work. But the facts that circumstances during the firefighters' work change very quickly and the evaporation speed depends on age, physical state etc. make the counts very difficult or almost impossible (Kóródi 2013).

Developments in the field of firefighter safety equipment are continuous throughout the world. Despite this, the interventional staffs have to suffer a great amount of heat charge during a long-lasting intervention, or during wearing heavy gas protective equipment in the presence of dangerous materials. The goal of the authors is to present the possibilities that can decrease temperature during firefighter interventions (Fejes & Kóródi 2014).

Adaptable temperature decreasing clothing

***Heat egress solutions by evaporation**.* At evaporation from the surface of the liquid molecules leave, which increase the steam-capacity of the room above the liquid. So evaporation is quite similar to boiling, because in both cases liquid turns into steam. The difference is that during evaporation molecules can leave only from the surface of the

liquid, while at boiling throughout the whole volume of the liquid can steam-bubbles appear which can lead to the intense movement of the whole liquid (Gribovszky 2010).
The reason of the evaporation is that the molecules on the surface of the liquid move inordinately. Because of their anomalous impacts they sometimes have such big kinetic energy that they can defeat their neighbour's magnetic interference and split from the surface of the liquid. Only those particles can do it that have the greatest kinetic energy, so they take energy away from the liquid. In other words, the average amount of energy of the rest of the particles decreases if those with the greatest level leave. Its consequence is that during evaporation the energy of the liquid decreases which is shown by the decrease of its temperature (USGS 2016).

The evaporation, the transformation of liquid into gas draws away a lot of energy. There are certain clothes that are made from special material and use this evaporation as cooling. Their material sups into a certain quantity of water, while thanks to its water resistant tarnish, the dress stays dry after wiping, as you can see in Figure 1. The dress thanks to the evaporation of the water becomes 5-7^{o}C cooler than its environment, and it can hold up to it for 5-10 hours long and we can achieve this only by ladling it into water for 1-3 minutes (Kovox 2011).

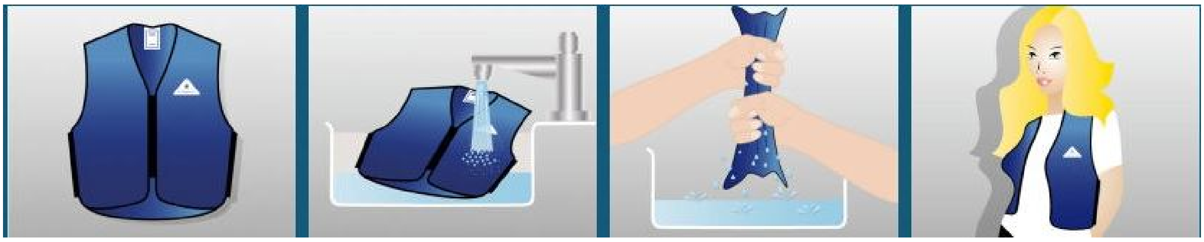

Figure 1. Heat egress solutions by evaporation (Source: Kovox Kft. 2011).

Setting heat-capacitors that draw away much heat on cryogenic surface. We need significant heat quantity for dissolving the crystal state of crystallisable materials, in other words for melting. They have another feature that until melting utterly happens, their temperature remains constant. By using this knowledge KOVOX Ltd. developed such a cooled piece of clothing that contains small cryogenic blocks, as you can see in Figure 2 (Kovox 2011). These cryogenic bags melt at 14^{o}C, at lower temperature than this they ensure a 14^{o}C temperature for three hours long during their melting. The producer offers his clothes having appropriate aggregate changer cooling solutions for steel factories and firefighter interventions. According to this, among the developed variations of clothes you can find the flameproof cooled vest as well.

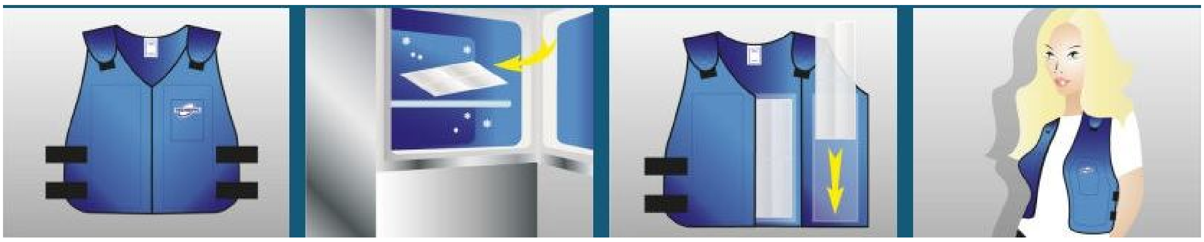

Figure 2. Setting heat-capacitors that draw away much heat on cryogenic surface (Source: Kovox Kft. 2011).

The circulation of liquid that is cooler than the environment in tubing built into clothes. Though clothes heated by electricity have been produced for a long time, a few years ago a Hungarian developer team came up with an entirely new solution. In the dress, designed by the Hungarian inventors, through narrow silicon tubes liquid circulates and its temperature can be set between 35 and 55^{o}C by the user. The 'liquid circulated clothes' can be used in a wider field than the electronic ones, because with this invention its wearer cannot only be heated, but cooled as well. The Thermoflash electronics system controls that with the help of small pumps we circulate special liquid in the tubing of the dress, as you can see in Figure 3. This liquid is absolutely harmless to health, monopropil-glikol based, and environmentally sound, not poisonous bio freezing-mixture. In the dress the tubes are placed to cover all the most significant parts of the body, and the designers also paid great attention to the fact that the whole surface of the body should be reached by the cold or warm (Hollenberger & Szállás 2010).

Figure 3. The circulation of liquid that is cooler than the environment in tubing built into clothes (Source: Thermofalsh Kft. 2010).

Conclusions. During hot weather – more or less according to the individual makings – every person's stamina decreases. Even above 20^{o}C we can sense such body reactions that not only obstruct the performance, but increase the intensive strain. At interventions firefighters have to do hard physical work under extreme circumstances. This counts especially at firefighters because a badly judged decision might cost his own or his partner's or the to-be-rescued civilians' lives.

Each firefighting intervention is risky. That is why our firefighters have to pay great attention to both their active and passive defence. With the use of the clothes presented by the authors we can increase the effectiveness of the interventions and the protection of our staff.

Acknowledgements. The work was created in commission of the National University of Public Service under the priority project KÖFOP-2.1.2-VEKOP-15-2016-00001 titled „Public Service Development Establishing Good Governance" in the Győző Concha Doctoral Program".

References

Cohen S., 1912 A study of temperature-coefficients and van 't Hoff's rule. KNAW, Proceedings, 14 (II) Amsterdam, pp. 1159-1173.

Fejes Z., Korodi G., 2014 Analysis of upper respiratory tract infections in mission circumstances. Academic and Applied Research in Military Science 13(1):47-52.

Gribovszky Z., 2010 Hidrológiai és hidraulikai alapok Nyugat - Magyarországi Egyetem. Available at: http://www.tankonyvtar.hu/hu/tartalom/tamop425/0027_MGIN7/ch01s04.htm. Accessed: November, 2016.

Hollenberger M., Szállás G., 2010 Hazai védőruha sikere Lipcsében. Védelem 2010 (4):17-19.

Kanyó F., 2008 A tűzoltók fizikai alkalmasságának felmérése az új évezredben: Laboratóriumi és pályavizsgáló teljesítménydiagnosztikai eljárások alkalmazási lehetőségei a tűzoltók teljesítménymérésében. ZMNE, pp. 24-27.

Kanyó F., 2014 A beavatkozó tűzoltók élettani paramétereit monitorozó telemetriás rendszeralkalmazási lehetőségei veszélyes anyag jelenlétében történő beavatkozásoknál. NKE, pp. 84-88.

Kovox Kft., 2011 http://www.kovox.hu/html/huto.futo.ruhazat.html#hutott, 2011 Accessed: Oktober, 2016.

Korodi G., 2013 Health screening examinations in cardiovascularrisk estimation. Academic and Applied Research in Military Science 12(1):39-44.
Lorenz R., Franz K., Krieger S., Zeilberger K., Jeschke D., 2007 Dynamische Leistungsfähigkeit bei reduzierter Wärmeabgabe in Feuerwehrschutzanzügen. Deutsche Zeitschrift fur Sportmedizin Jahrgang 58(5):132-137.
Nádori L., Derzsi B., Fábián G., Ozsváth K., Rigler E., Zsidegh M., 1998 Sportképességek mérése. TF tankönyv Budapest, pp. 300-312.
Pavlik G., 2013 Sportélettan Medicina Könyvkiadó Zrt. ISBN: 9789632263410, pp. 32-35.
Petrekanits M., 2002 Fizikai Vizsgálat a Ferihegyen Védelem (6):30-31. Available at: http://www.vedelem.hu/letoltes/ujsag/v200206.pdf?13. Accessed: December, 2016.
Rita F., Paul R., Joseph L., 2016 Firefighter deaths by cause and nature of injury NFPA. Available at: http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/the-fire-service/fatalities-and-injuries/firefighter-deaths-by-cause-and-nature-of-injury. Acessed: December, 2016.
Rita F., Paul R., Joseph L., 2016 Firefighter fatalities in the United States NFPA. Available at: http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/the-fire-service/fatalities-and-injuries/firefighter-fatalities-in-the-united-states. Acessed: December, 2016.
Thermoflash Kft., 2010 The circulation of liquid that is cooler than the environment in tubing built into clothes. Available at: http://www.tesztmotor.hu/tesztek/felfutott_allapotban_teszteltunk_thermoflash. Accessed: December, 2016
USGS Water Science School, 2016 The water cycle: evaporation. Available at: https://water.usgs.gov/edu/watercycleevaporation.html. Accessed: November, 2016.

Received: 18 January 2017. Accepted: 29 March 2017. Published online: 30 March 2017.
Authors:
Anett Urban, Institute of Disaster Management, National University of Public Service; 9-11 Hungária körút, Budapest 1101, Hungary, e-mail: urban.anett@uni-nke.hu
Ágoston Restás, Institute of Disaster Management, National University of Public Service; 9-11 Hungária körút, Budapest 1101, Hungary, e-mail: Restas.Agoston@uni-nke.hu

How to cite this article:
Urban A., Restás Á., 2017 Making body temperature lower to raise the safety level of firefighters' intervention. Ecoterra 14(1):47-51.